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Foraging Effects of the Invasive Alien Fish *Pterygoplichthys* on Eggs and First-Feeding Fry of the Native *Clarias macrocephalus* in Thailand

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ABSTRACT

Native to Latin America, the sailfin armored catfish *Pterygoplichthys* has been introduced to Thailand for the ornamental fish industry. This invasive species has flourished in nature and may threaten aquatic resources, especially of indigenous freshwater fish due to its foraging activities. This study investigated the biological impacts of the sailfin armored catfish on the eggs and the first-feeding fry of the Thai native catfish, *Clarias macrocephalus* that are found in similar habitats. The results showed that small, medium and large *Pterygoplichthys* fed on up to 95% or more of native catfish eggs within 24 hr. *Pterygoplichthys* also consumed the first-feeding fry of *C. macrocephalus*. The average consumption of first-feeding fry by small, medium and large *Pterygoplichthys* was 26.3±7.2, 71.8±23.5 and 86.3±13.7%, respectively. These results clearly indicated that the consumption of the catfish eggs was much higher than for the first-feeding fry primarily due to the fact that the eggs were immobile and accessible. In addition, the consumption rates of first-feeding fry by the armored catfish were positively correlated with the size of *Pterygoplichthys* (correlation coefficient = 0.6238, $P < 0.01$). In conclusion, *Pterygoplichthys* can destroy the eggs and first-feeding fry of the native catfish *Clarias macrocephalus* and has the potential to reduce the populations of Thai native fish species.

Keywords: invasive alien fish, sailfin armored catfish, foraging impact, Thailand

INTRODUCTION

Thailand, like many other tropical countries, is rich in biological resources. In particular, according to FishBase, approximately 836 fish species are found in the country (Froese and Pauly, 2011). However, the number of Thai native fish species has declined steadily. It is probable that this decline may have resulted from the introduction of nonindigenous species, one of the crucial threats to biodiversity worldwide (Crowl *et al.,* 1992; Lowe *et al.,* 2000; Munro *et al.,* 2005; Hubilla *et al.,* 2007). Reductions in biodiversity are of global concern, as indicated by the designation of 2011–2020 as the Decade on Biodiversity by the General Assembly of the

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United Nations. (Sala *et al.*, 2000; Dirzo and Raven, 2003; Butchart *et al.*, 2010).

A recent study showed that the populations of Thai native fish had declined in a canal in which *Pterygoplichthys*, an invasive exotic fish, became established (Chaichana *et al.*, 2011). Several other studies have also shown that introducing non-native fish can threaten the diversity of native fish. For example, the introduction of rainbow trout (*Oncorhynchus mykiss*, Salmonidae) into Lake Titicaca, Peru, for fisheries caused the local extinction of local fish (Rosenthal, 1980). Latini and Petrere (2004) also indicated that the presence of alien fish, such as *Cichla* cf. *monculus* and *Astronotus ocellatus*, reduced the richness and diversity of the native fish community in the River Doce basin, Brazil. Furthermore, the extinction of three native fish species of the genus *Phoxinellus* was attributed to the introduction of *Stizostedion lucioperca* to lakes in the northern Mediterranean region (Crivelli, 1995).

Introduced fish species may produce many adverse impacts on native fish populations through competition for food and habitat, predation, diseases, habitat alteration and genetic contamination through hybridization (Crowl and Boxrucker, 1990; Crowl *et al.*, 1992; Na-Nakorn *et al.*, 2004; Cook-Hildreth, 2009). Although *Pterygoplichthys* is known to be algivorous and detritivorous, typically feeding on algae and detritus that cover submerged surfaces, its foraging activities may have a potentially adverse effect on egg survival in native species (Hoover *et al.*, 2004) and perhaps on first-feeding fry.

This study investigated the impacts of *Pterygoplichthys* predation on the eggs and first-feeding fry of *Clarias macrocephalus*. This investigation was motivated by the increasing concern that in a shared habitat, *Pterygoplichthys* may cause reductions in native fish populations through intentional or unintentional predation. No experimental studies have investigated the ability of *Pterygoplichthys* to consume the eggs and first-feeding fry of *C. macrocephalus*, a demersal species with a habitat similar to that of *Pterygoplichthys.* The understanding of predation on native fish by this invasive species can help protect native Thai species from extinction.

MATERIALS AND METHODS

Samples of *Pterygoplichthys* were obtained from the Nong Yai canal (12º57'38.77"N, 100º54'47.60"E), located in Chonburi province, eastern Thailand. The fish were captured with a large seine net in September 2009. The samples of *Pterygoplichthys* were subsequently transferred to two 1 t fiberglass containers. The water was sufficiently oxygenated at all times. The fish were kept at Kasetsart University and fed daily with commercial pellet food from 1500–1600 hours. The environmental conditions were maintained to allow the fish to become familiar with their surroundings and to attain excellent physical condition. After 30 d, healthy and active individuals of different sizes of *Pterygoplichthys* were randomly selected for the subsequent experiments (Figure 1). Eggs and first-feeding fry of *C. macrocephalus* were obtained from the Department of Aquaculture, Kasetsart University, Kamphaeng Saen campus.

The experiments were performed in the Aquaculture Laboratory, Department of Aquaculture, Faculty of Fisheries, Kasetsart University, Bangkok. Twelve aquaria, 30×60×45 cm in size, were used. Each experimental aquarium contained 53 L of chlorine-free tap water. The water was oxygenated at a rate of 750 mL.min^{-1}. After 3 d, individual small-sized (weight 2±0.0 g, standard length 4.3±0.1 cm), medium-sized (weight 83.8±2.0 g, standard length 16.2±0.2 cm) and large-sized (weight 537.8±51.3 g, standard length 33.4±1.3 cm) *Pterygoplichthys* were randomly released, one fish per aquarium. Four replicate aquaria were used for *Pterygoplichthys* of each body size. Prior to the experiment, samples of *Pterygoplichthys* were held in these aquaria for 2 wk to accustom the fish to the new environment.

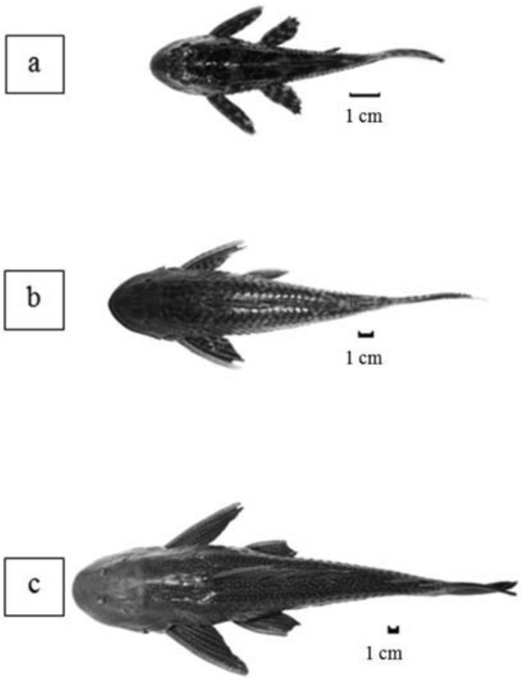

Figure 1 *Pterygoplichthys* of different sizes: (a) Small, standard length 4.2–4.4 cm; (b) Medium, 16.0–16.5 cm; and (c) Large, 32.1–35.5 cm.

During this period, the fish were fed to satiation with commercial pellet food daily from 1500–1600 hours and 50% of the water was replaced every 3 d.

The individual *Pterygoplichthys* were not fed for 48 hr before the experiment. Two experiments were performed, and a completely randomized design was used for each experiment. In Experiment I, the foraging activities of *Pterygoplichthys* on catfish eggs were investigated. One hundred catfish eggs were released in each aquarium. After 24 hr, the remaining eggs were removed by suction using a hose. The feeding efficiency of the fish was measured by calculating the percentage of fish eggs eaten. Experiment II was performed to investigate feeding by *Pterygoplichthys* on first-feeding fry. After the end of Experiment I, the experimental fish were held for 7 d to ensure that they were in adequate condition before the beginning of Experiment II. One hundred first-feeding fry were placed in each experimental aquarium. After 24 hr, the remaining first-feeding fry were captured and counted. The feeding efficiency of the fish was measured by calculating the percentage of fry eaten. During both experiments, direct observations of the fish and feeding behavior were made and a video camera was used to record feeding behavior.

The water quality in each experimental aquarium was measured every 6 hr throughout the experiments. The dissolved oxygen (milligrams per liter) and water temperature (degrees Celcius) were measured with a YSI 85-10FT system (YSI Incorporated; Yellow Springs, Ohio, USA). The pH was measured with a YSI 60-10FT system (YSI Incorporated; Yellow Springs, Ohio, USA).

A one-way analysis of variance was applied to test the differences among the means in each experiment at the 5% level of significance. The percentage data were arcsine transformed before analysis. Multiple comparisons between pairs of means were also performed with Duncan's new multiple range test. The analysis of the correlation between the size of *Pterygoplichthys* and the consumption of catfish eggs and first-feeding fry was performed using regression methods.

RESULTS

The foraging activities of *Pterygoplichthys* appeared to decrease the survival of *C. macrocephalus* eggs. After 24 hr exposure, the efficiency of feeding on the eggs by small, medium and large *Pterygoplichthys* was 95.5±5.6, 99.3±0.8 and 99.3±0.8%, respectively (Table 1). There was no significant difference in the efficiency of feeding on eggs among the different-sized *Pterygoplichthys*.

The survival rate of first-feeding fry after 24 hr exposure to *Pterygoplichthys* is shown in Table 2. Although *Pterygoplichthys* fed on the first-feeding fry, the feeding efficiency was lower than that found when feeding on eggs. The efficiency of feeding on first-feeding fry by small, medium, and large *Pterygoplichthys* was 26.3±7.2, 71.8±23.5 and 86.3±13.7%, respectively. The statistical analysis indicated that medium and large *Pterygoplichthys* fed more efficiently than did the small fish.

The rate of feeding on eggs was not correlated with the size of *Pterygoplichthys* (correlation coefficient (r^2) = 0.1465, $P > 0.05$) as shown in Figure 2. In contrast, a positive correlation was found between the rate of feeding on first-feeding fry and the size of *Pterygoplichthys* ($r^2 = 0.6238$, $P < 0.01$) as shown in Figure 3.

Water quality during experimentation

The water quality, including dissolved oxygen, pH and temperature, was satisfactory for all treatments (Table 3) compared with the water quality standard in Duangsawat and Somsiri (1985). The average dissolved oxygen in aquaria containing small, medium or large *Pterygoplichthys* was 7.62±0.79, 7.39±0.78 and 7.01±0.80 $mg.L^{-1}$, respectively. The pH ranged between 7.39±0.06 and 8.28±0.07, and the temperatures ranged between 29.4±0.2 and 30.8±0.3 ^{0}C. Overall, the water quality did not differ statistically among treatments.

DISCUSSION

The results of the study clearly indicated that *Pterygoplichthys* of different sizes could consume virtually all of the catfish eggs immediately after the eggs were released into the

Table 1 Number of remaining catfish eggs and egg-feeding efficiency of different-sized *Pterygoplichthys* over 24 hr.

Replicate	Remaining *Pterygoplichthys* eggs (Number)			*Pterygoplichthys* egg-feeding efficiency (%)		
	Small	Medium	Large	Small	Medium	Large
1	14	0	1	86	100	99
2	0	2	0	100	98	100
3	3	0	0	97	100	100
4	1	1	2	99	99	98
Mean±SD	5±6	1±1	1±1	95.5±5.6[a]	99.3±0.8 [a]	99.3±0.8 [a]

Values in the same row with same lowercase superscript letters are not statistically different ($P > 0.05$).

Table 2 Number of remaining first-feeding fry and efficiency of feeding on first-feeding fry by different-sized *Pterygoplichthys* over 24 hr.

Replicate	Remaining *Pterygoplichthys* first-feeding fry (Number of individuals)			Egg-feeding efficiency on *Pterygoplichthys* first-feeding fry (%)		
	Small	Medium	Large	Small	Medium	Large
1	72	68	10	28	32	90
2	63	12	37	37	88	63
3	82	10	3	18	90	97
4	78	23	5	22	77	95
Mean±SD	74±7	28±24	14±14	26.3±7.2[a]	71.8±23.5 [b]	86.3±13.7 [b]

Values in the same row with different lowercase superscript letters are statistically different ($P < 0.05$).

aquarium. The explanation for this finding could be that the very small size of the catfish eggs at 655 eggs.g^{-1} (Na-Nakorn, 1995) allowed different-sized *Pterygoplichthys* to consume the eggs at the same rate ($P > 0.05$). However, the medium- and large-sized *Pterygoplichthys* consumed the eggs 2–3 hr sooner than the small-sized fish. The current results were consistent with the findings of Cook-Hildreth (2009) that the survival rate of eggs of the fountain darter, *Etheostoma fonticola*, was substantially lower when the eggs were exposed to foraging armored catfish and that eggs were found in the digestive tracts of the experimental armored catfish. These findings suggested that exotic fish may reduce the breeding success of the local fish in shared habitats.

Pterygoplichthys could consume the first-feeding fry of *C. macrocephalus*, but the consumption rates were lower than those for the catfish eggs. The differential accessibility of food could be an explanation of this result. The eggs may have been more easily accessible to foraging *Pterygoplichthys* than the first-feeding fry and may therefore have been at a higher risk. The first-

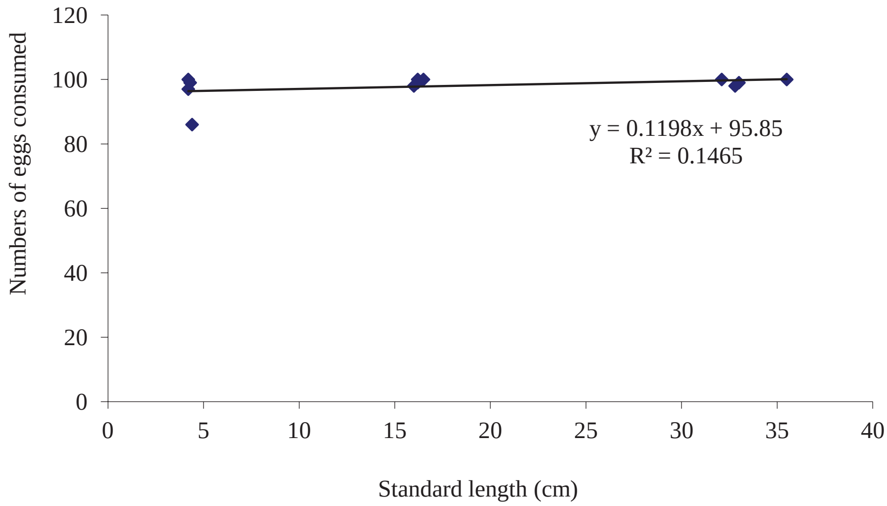

Figure 2 Correlation between number of catfish eggs consumed in 24 hr and the standard length of *Pterygoplichthys*.

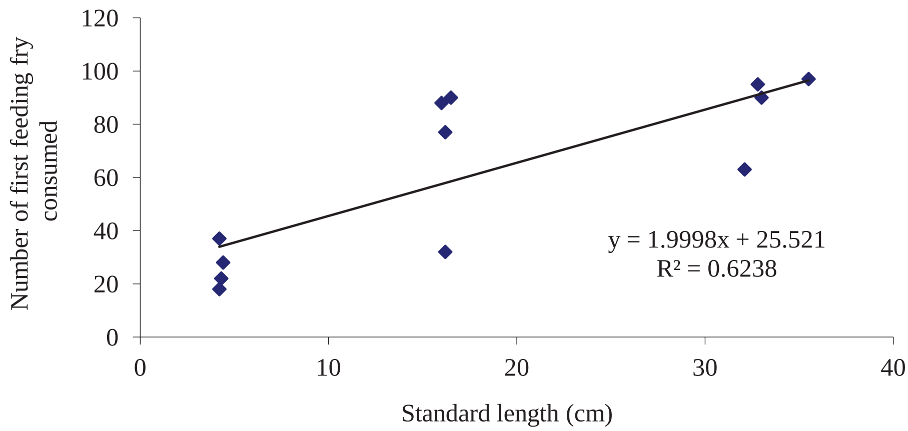

Figure 3 Correlation between number of catfish first-feeding fry consumed in 24 hr and the standard length of *Pterygoplichthys*.

feeding fry of *C. macrocephalus* were observed to swim as a group and tended to remain in the top corners of the aquarium and near the surface of the water to avoid predation by *Pterygoplichthys*. To feed on the first-feeding fry, *Pterygoplichthys* swam up to the surface and pursued a school of fry. However, *Pterygoplichthys* remained at the bottom or in contact with the sides of the aquarium during the non-feeding period.

The rate of consumption of the first-feeding fry by the armored catfish was positively correlated with the size of the armored catfish ($r^2 = 0.6238$). The young and adult *Pterygoplichthys* fed in different ways and this was consistent with Gerking (1994) stating that the larval fish do not follow the same pattern of feeding as do adults. When the first-feeding fry were placed in the aquarium, the small *Pterygoplichthys* did not respond to the fry until nighttime and then began to pursue the prey. In contrast, the medium-sized *Pterygoplichthys* began to respond to the fry sooner than did the small fish. The large *Pterygoplichthys* immediately pursued and fed on the fry. The feeding response of the large *Pterygoplichthys* was more immediate than the feeding responses of the small- and medium-sized *Pterygoplichthys*. The different responses of the small-, medium- and large-sized *Pterygoplichthys* to the first-feeding

Table 3 Water quality in the experimental aquaria containing small, medium, and large sailfin armored catfish (mean±SD, n = 4).

Water quality	Experimental aquaria containing different-sized *Pterygoplichthys*		
	Small	Medium	Large
Dissolved Oxygen ($mg.L^{-1}$)			
Initial	8.75±0.55	8.69±0.05	8.36±0.28
At 6 hr	7.70±0.33	7.24±0.34	6.97±0.22
At 12 hr	7.64±0.39	7.34±0.21	6.83±0.08
At 18 hr	7.49±0.33	7.10±0.19	6.60±0.41
At 24 hr	6.54±0.27	6.58±0.09	6.29±0.19
Overall mean	7.62±0.79[a]	7.39±0.78[a]	7.01±0.80[a]
pH			
Initial	8.28±0.07	8.15±0.06	7.83±0.07
At 6 hr	7.73±1.04	8.13±0.07	7.86±0.04
At 12 hr	8.23±0.07	8.12±0.06	7.87±0.08
At 18 hr	8.19±0.05	8.12±0.05	7.88±0.07
At 24 hr	7.52±0.03	7.43±0.05	7.39±0.06
Overall mean	7.99±0.34[a]	7.99±0.31[a]	7.77±0.21[a]
Temperature (^{o}C)			
Initial	29.9±0.6	29.7±0.3	29.8±0.3
At 6 hr	30.4±0.8	30.1±0.3	30.1±0.3
At 12 hr	29.9±0.5	29.7±0.3	29.7±0.3
At 18 hr	29.5±0.4	29.4±0.3	29.4±0.2
At 24 hr	30.8±0.3	30.7±0.3	30.6±0.2
Overall mean	30.1±0.5[a]	29.9±0.5[a]	29.9±0.5[a]

[a] = No statistical difference ($P > 0.05$).

fry could have resulted from previous feeding experience. The mature *Pterygoplichthys* were more capable of tracking the first-feeding fry than the younger and smaller *Pterygoplichthys*. In addition, the larger *Pterygoplichthys* have stronger and larger mouths and thus a greater ability to capture and feed on first-feeding fry than younger fish. Hansen and Wahl (1981) studied at-size perch feeding on *Daphnia pulex* in Oneida Lake, New York and found that perch below 27.8 mm in length are constrained by their mouth width to eat only the smaller size classes of *Daphnia*. These findings imply that in a shared habitat where large *Pterygoplichthys* are abundant, the local fish population may be affected more strongly than in an area dominated by smaller *Pterygoplichthys*. Chaichana *et al.* (2011) reported that the decline in the native fish population was relatively greater in a habitat shared with large *Pterygoplichthys* than in the sites where young *Pterygoplichthys* were abundant.

CONCLUSION

The foraging activities of different-sized *Pterygoplichthys* had potentially strong negative effects on the number of catfish eggs and first-feeding fry. Therefore, these invasive alien fish pose a risk to the native aquatic resources of Thailand. Government agencies should adopt serious measures now to prevent such fish from spreading across the region. Furthermore, the elimination of these nonnative fish is urgently needed to prevent the future reduction of native Thai freshwater fish species.

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